

A photograph of the Mühleberg Nuclear Power Plant, featuring a large containment dome and a tall chimney with red and white stripes, situated behind a dense line of green trees along a river. The sky is blue with scattered white clouds.

# Nuclear Power Plant Mühleberg – Decommissioning

Radiological characterization to lay the foundation of ALARA. Experience from Mühleberg NPP

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# Radiological characterization to lay the foundation of ALARA

## Characterization in principle – tasks and stakeholders

- The characteristics of systems, components, rooms & buildings are to be described (physical parameter, industrial safety hazards, radiological parameter).
- By the characterization mass- and activity flows must be shown (disposal planning).
- Who are the stakeholders, needing information for planning
  - Dismantling (i.e. remote controlled dismantling, techniques for dismantling etc.)
  - Logistics (i.e. safe transports and buffer capacities)
  - Waste treatment (i.e. installations for mechanic and thermal cutting, wet and / or dry decontamination aso.)
  - Conditioning radioactive waste (i.e. installations, qualification of the procedures, packaging, transport conditions with respect to Hazardous Cargo Ordinance Class 7 aso.)
  - Clearance (i.e. procedures, equipment for clearance of components and release of buildings and sites, determination of nuclide vectors aso.)
  - Radiation protection (individual and collective dose, protection measures, kind of measurements, shielding, meeting the radioactivity limits for effluents etc.)
  - Occupational work safety (i.e. protection measures, treatment procedures and disposal planning for non radioactive hazardous wastes)
  - Decommissioning costs (i.e. timely arising of costs)



## Characterization in principle – tasks and stakeholders



## Measures

### Parameter

## Stakeholder

## Benefits

# Systems

## Dismantling

## Employee protection

## Disposal

## Time efficiency

Logistics

## Release of Areal- & buildings from KEG

## Cost development

Mass

## Volume

Occupational- & radiation protection

## Seriousness of planning

Area

## Projects/Processes/ Releases

## Documentation

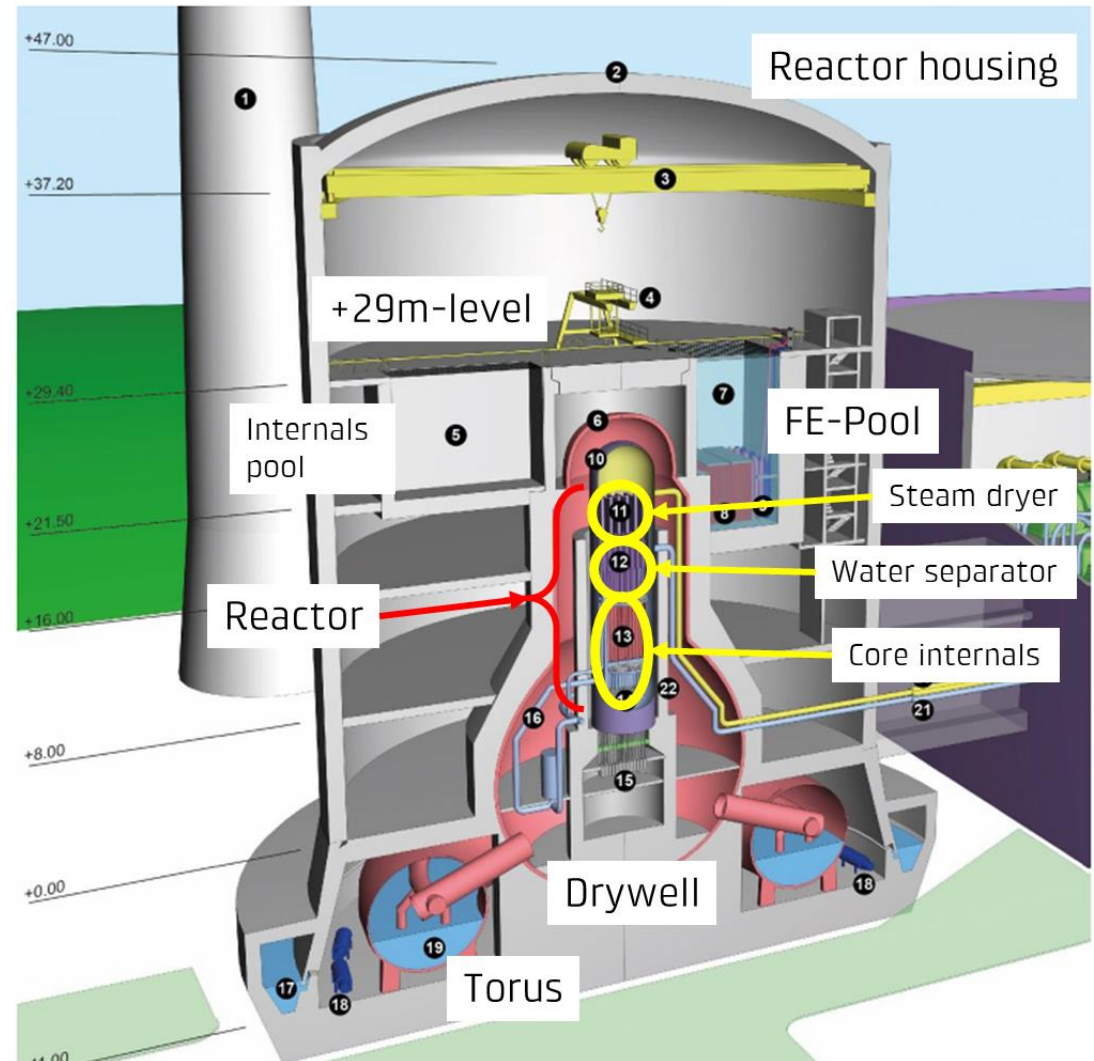
## Services business

# Radiological characterization to lay the foundation of ALARA

## Radiological Characterization – activation RPV and surroundings

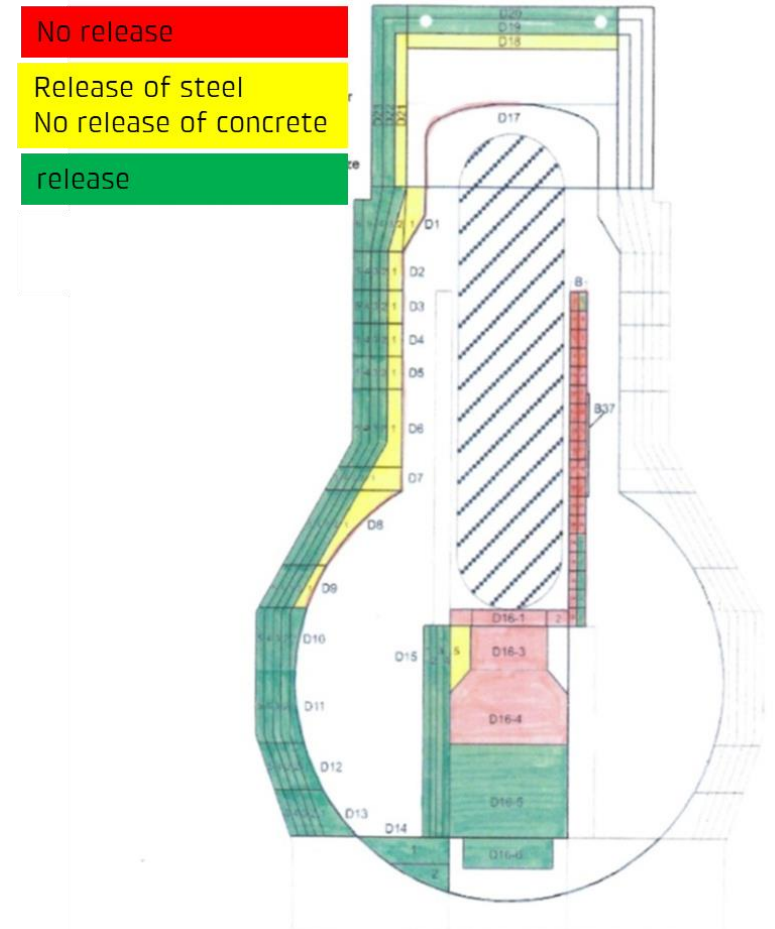
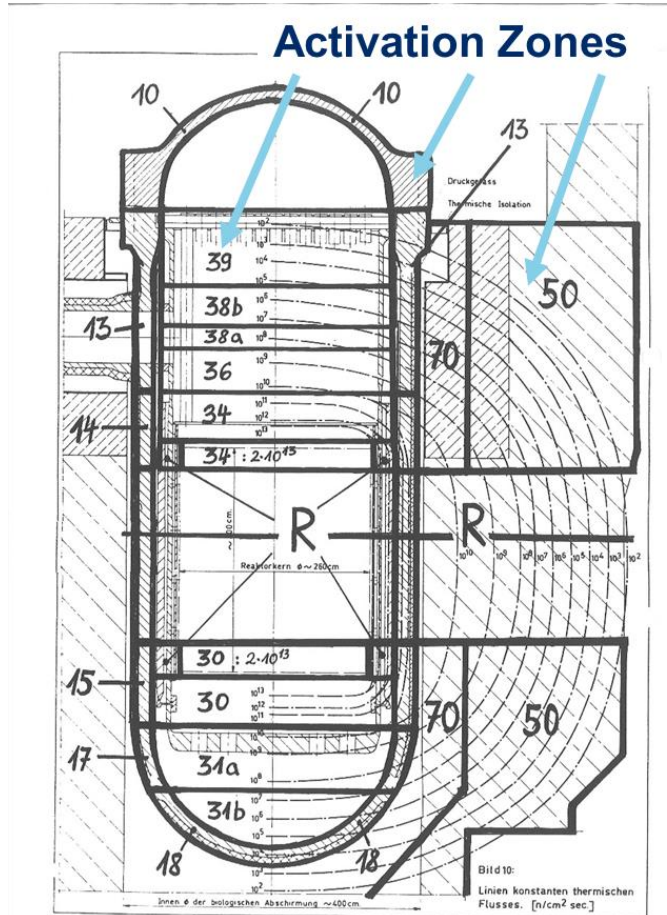
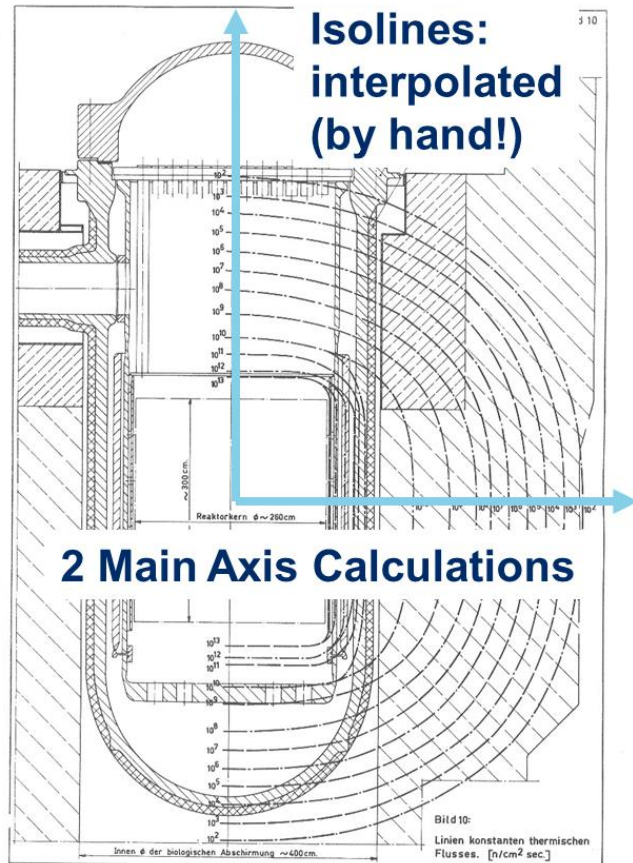
Characterization with respect to activation is a mixture of two aspects:

- Preparation aspects, to be considered in advance to take samples
  - Material composition of the components in the activation area including impurities
  - Activation area including scattering
  - Activation reactions possible with respect to the beam and scattering
  - Activation products possible and their decay half time
- Exclusion of special nuclides, difficult to measure due to: probability of the reaction (even exotic), irrelevance because of half time, high clearance levels or only a very low possible radioactivity, measurement limitations (sample masses, decay time, ....)



# Radiological characterization to lay the foundation of ALARA

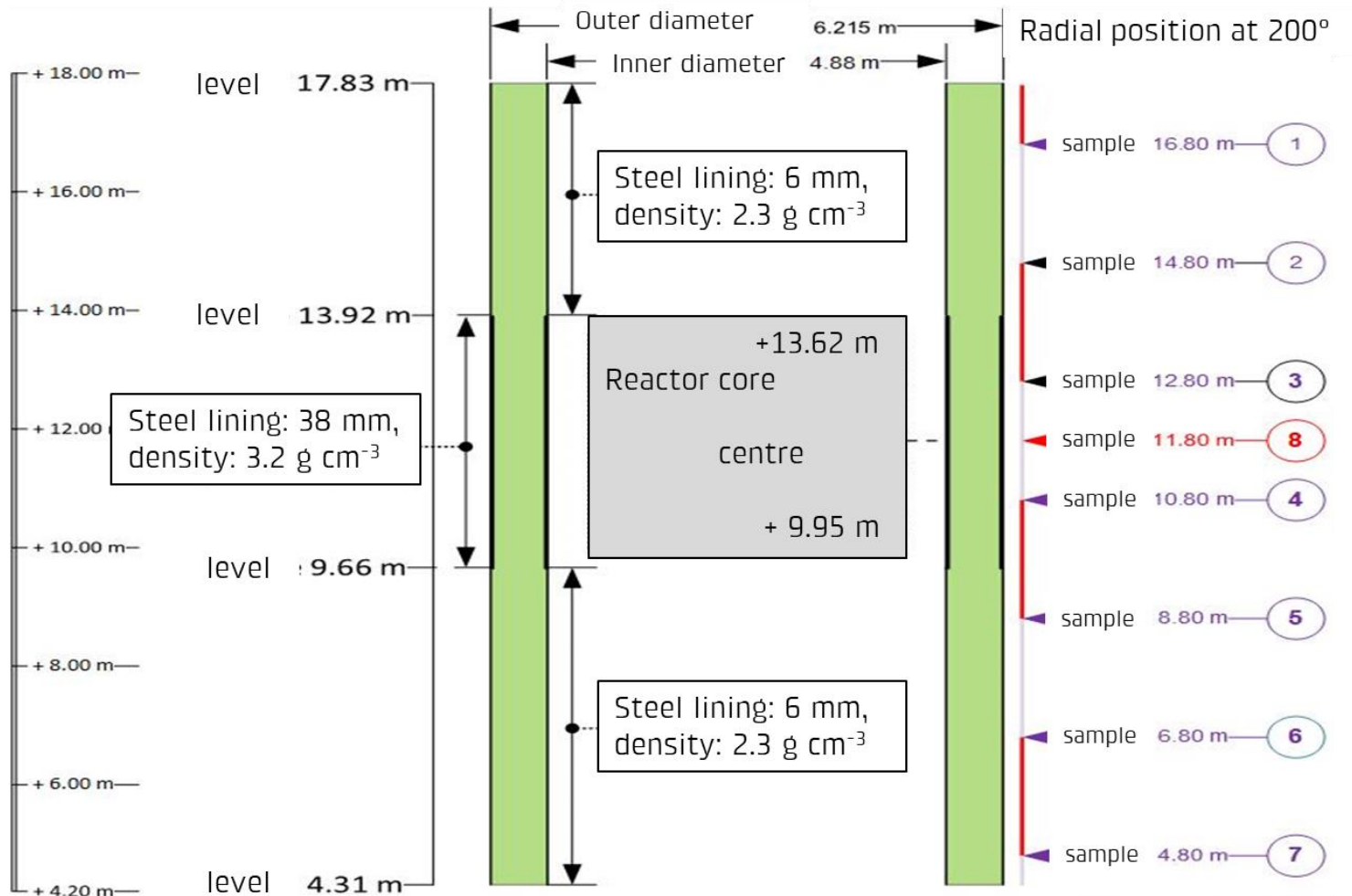
## Activation RPV and surroundings - past





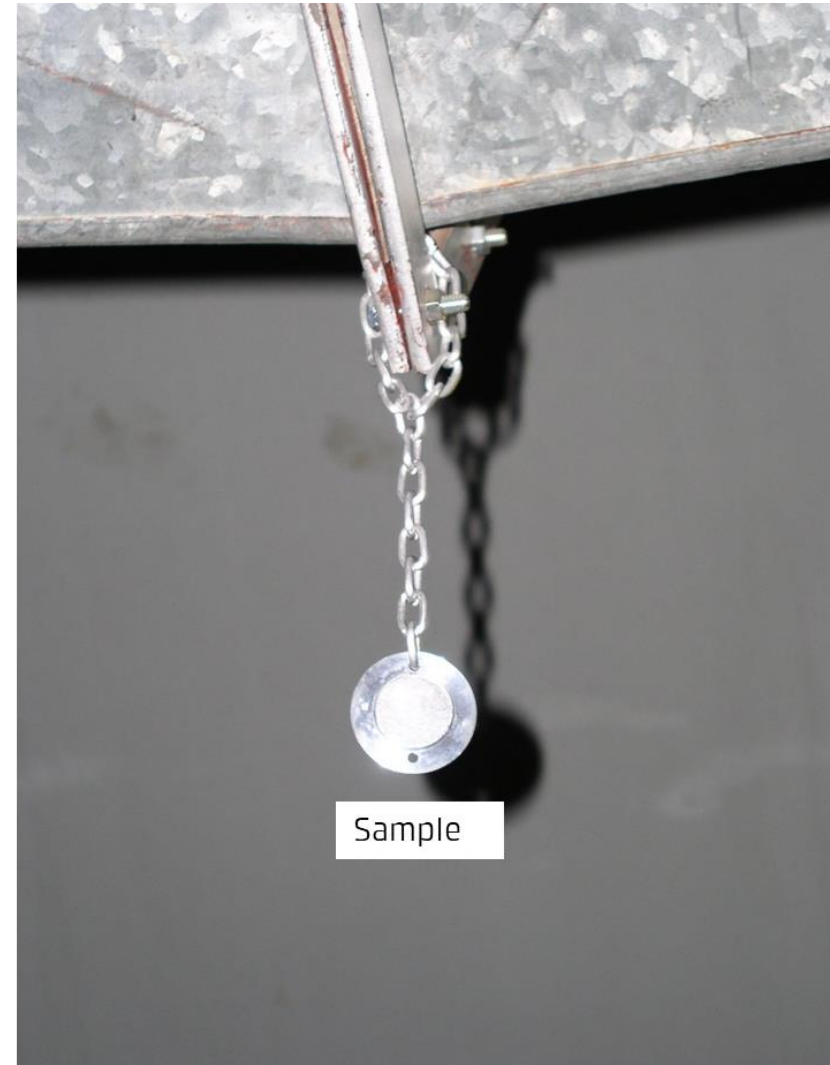
# Radiological characterization to lay the foundation of ALARA

## Activation RPV and surroundings – first innovation



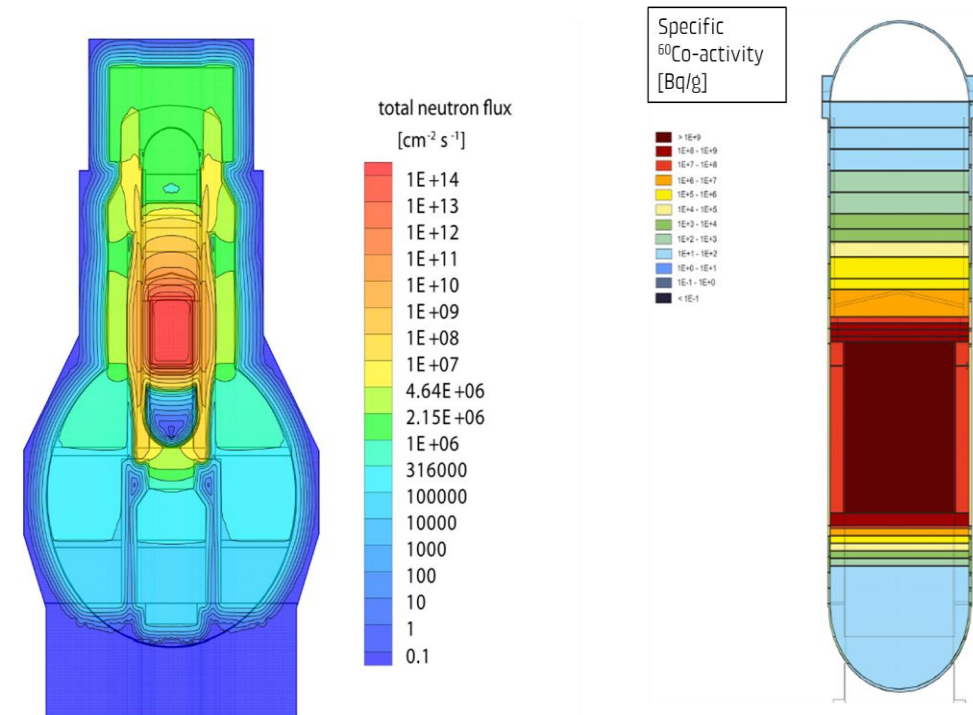
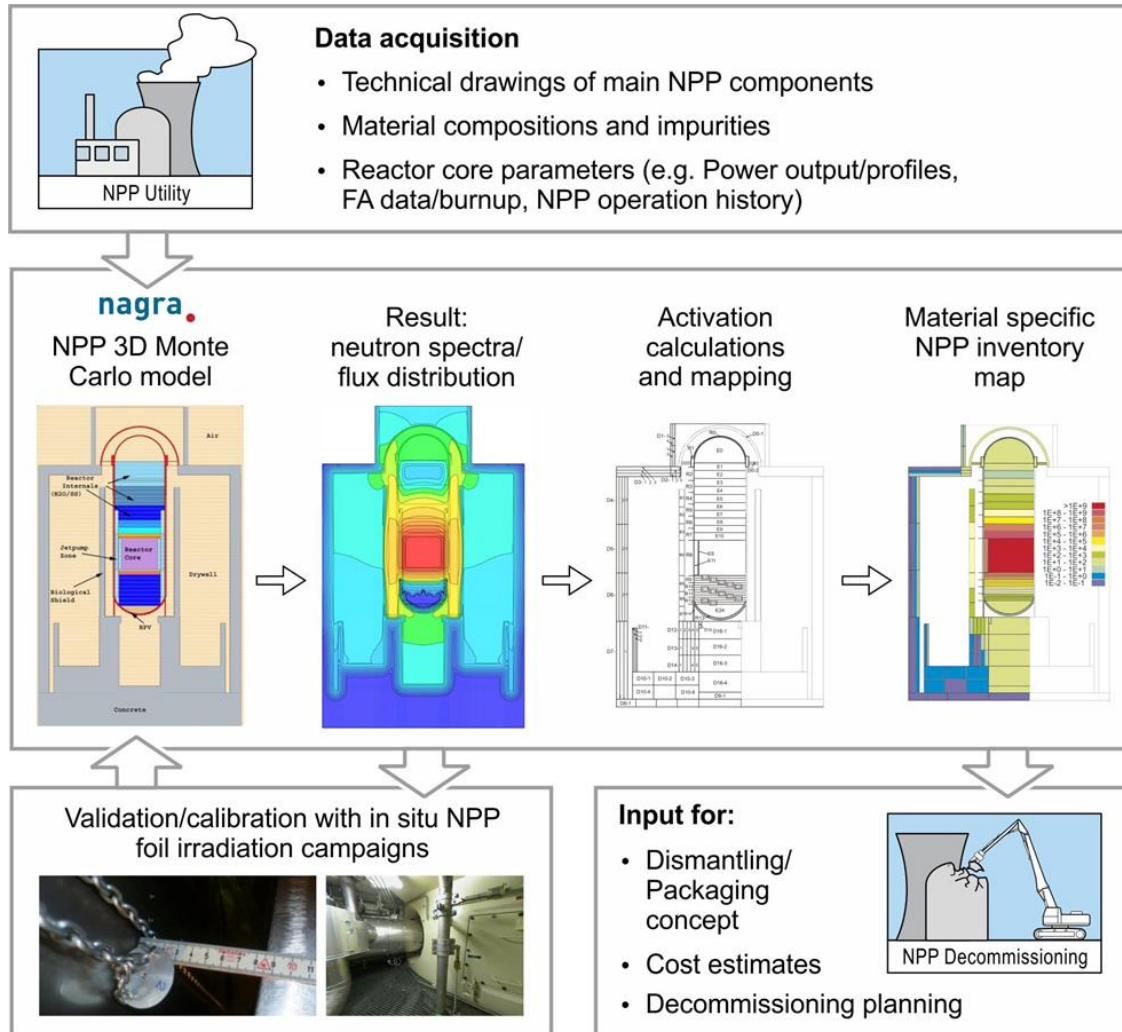
# Radiological characterization to lay the foundation of ALARA

## Activation RPV and surroundings – first innovation



# Radiological characterization to lay the foundation of ALARA

## Activation RPV and surroundings – results step I



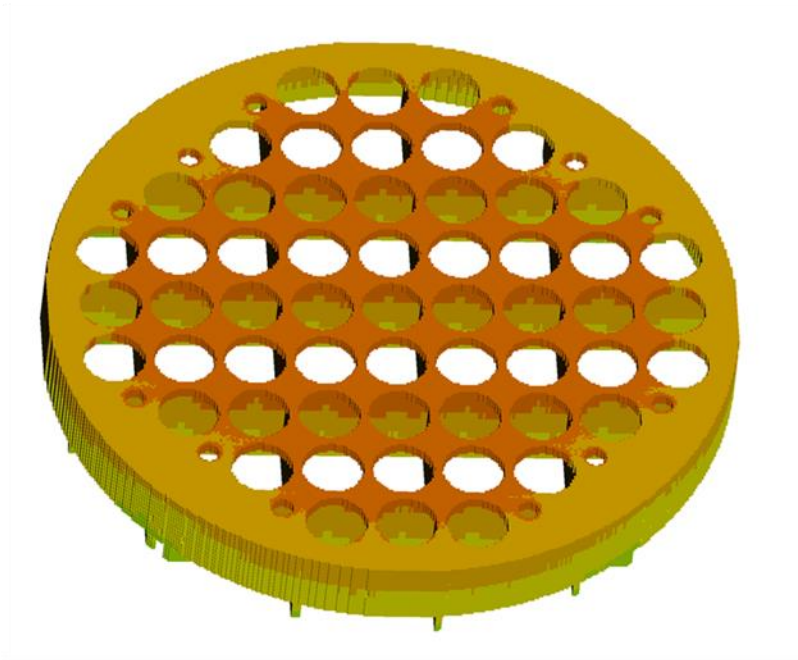
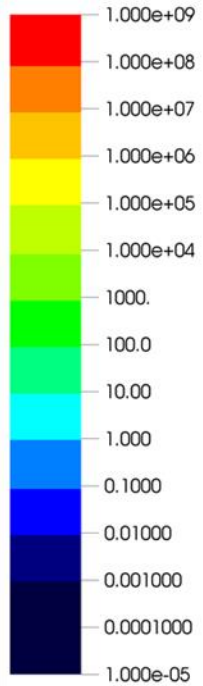


# Radiological characterization to lay the foundation of ALARA

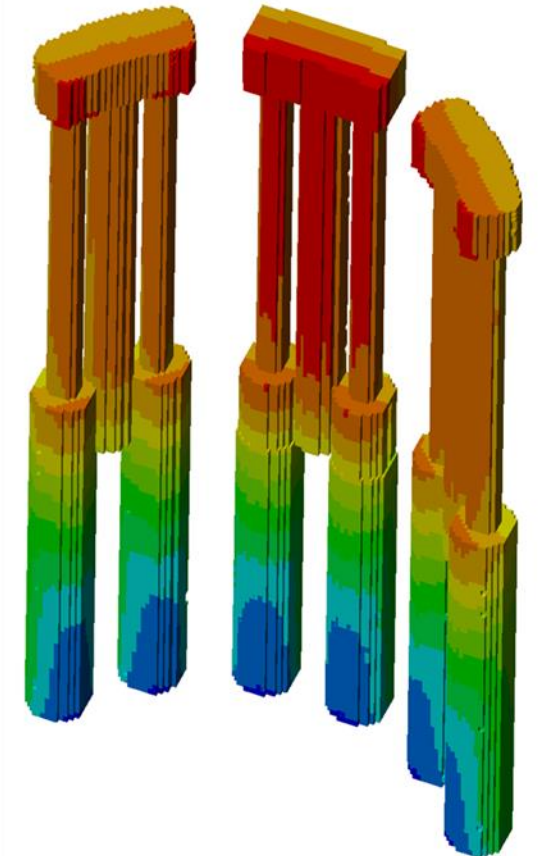
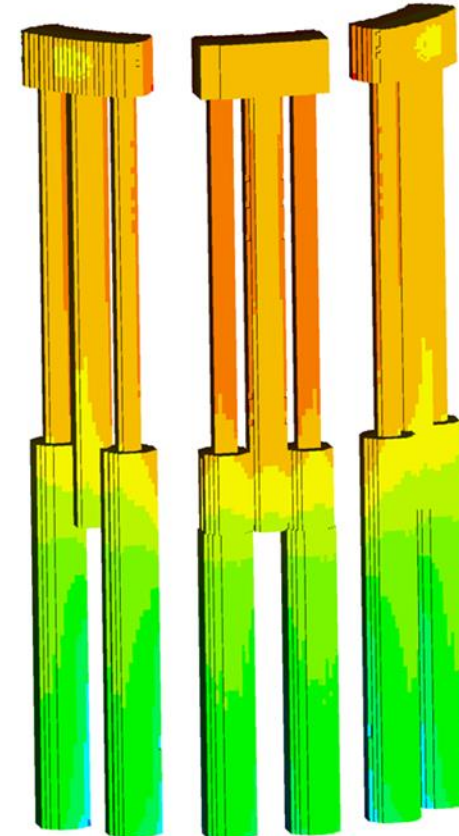
## Activation RPV and surroundings – results step II

Core grid

Co<sup>60</sup> [Bq/g]



Jet pumps



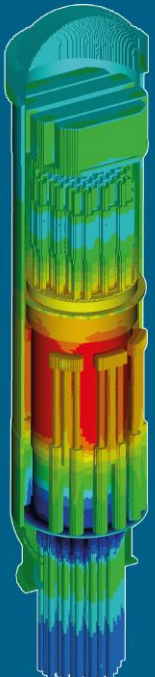
# Radiological characterization to lay the foundation of ALARA

## Activation RPV and surroundings – results step II, optimized packaging

Define the setup for the segmentation of each component taking into account the individual radiological situation (i.e. dose rate field expected)

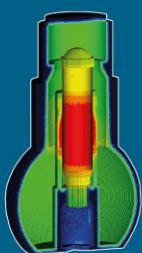
Planning of the packaging concept by optimized filling of the container types and variants available

**AMAC – Nagra's Advanced Methodology for Activation Characterization**



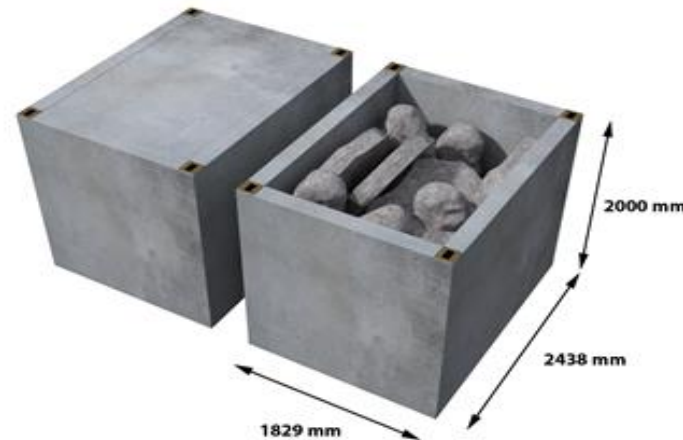
- COMPONENT-WISE 3D ACTIVATION ATLAS
- OVER 90% REDUCTION IN RADIOLOGICAL SAMPLING NEEDS
- OPTIMAL BASIS FOR SEGMENTATION AND PACKAGING STRATEGIES
- DECOMMISSIONING COST REDUCTION
- FACILITATING INTERACTION WITH THE REGULATOR

Nagra's AMAC approach has already been successfully tested, verified and applied in many decommissioning projects of NPPs and research reactors in Switzerland and abroad.



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Head International Services and Projects  
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low radioactive waste

\$



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medium radioactive waste

# Radiological characterization to lay the foundation of ALARA

## Characterization – Planning packaging

Mass [t]	Packaging Density [g/cm <sup>3</sup> ]	Total Activity [TBq]
8.4	2.4	1.2E+03

?

Cask Type	Cask Volume [dm <sup>3</sup> ]	Activity Limit [TBq]
Stahlblech TypeIV	6500	1.7E-02
Stahlblech TypeV	9800	1.7E-02
MOSAIIK-II 0mm	490	4.3E-01
MOSAIIK-II 20mm	408	1.2E+00
MOSAIIK-II 25mm	392	1.6E+00
MOSAIIK-II 30mm	375	2.2E+00
MOSAIIK-II 35mm	361	2.9E+00
MOSAIIK-II 40mm	347	3.8E+00
MOSAIIK-II 45mm	333	5.0E+00
MOSAIIK-II 50mm	320	6.6E+00
MOSAIIK-II 55mm	306	8.7E+00
MOSAIIK-II 60mm	294	1.1E+01
MOSAIIK-II 65mm	281	1.5E+01
MOSAIIK-II 70mm	269	2.0E+01
MOSAIIK-II 75mm	258	2.6E+01
MOSAIIK-II 80mm	246	3.3E+01
MOSAIIK-II 85mm	235	4.4E+01
MOSAIIK-II 90mm	225	5.7E+01
MOSAIIK-II 95mm	213	7.4E+01
MOSAIIK-II 100mm	203	9.8E+01
MOSAIIK-II 105mm	193	1.3E+02
MOSAIIK-II 110mm	184	1.7E+02
MOSAIIK-II 115mm	175	2.2E+02
MOSAIIK-II 120mm	166	2.8E+02

Cask Type	Volume [dm <sup>3</sup> ]	# of cask	Activity/cask [TBq]	Activity Limit [TBq]	Activity Limit Consumption
Stahlblech TypeIV	6500	0.5	2.2E+03	1.7E-02	>100%
Stahlblech TypeV	9800	0.4	3.4E+03	1.7E-02	>100%
MOSAIIK-II 0mm	490	7.2	1.7E+02	4.3E-01	>100%
MOSAIIK-II 20mm	408	8.6	1.4E+02	1.2E+00	>100%
MOSAIIK-II 25mm	392	9.0	1.3E+02	1.6E+00	>100%
MOSAIIK-II 30mm	375	9.4	1.3E+02	2.2E+00	>100%
MOSAIIK-II 35mm	361	9.7	1.2E+02	2.9E+00	>100%
MOSAIIK-II 40mm	347	10.1	1.2E+02	3.8E+00	>100%
MOSAIIK-II 45mm	333	10.5	1.1E+02	5.0E+00	>100%
MOSAIIK-II 50mm	320	11.0	1.1E+02	6.6E+00	>100%
MOSAIIK-II 55mm	306	11.5	1.1E+02	8.7E+00	>100%
MOSAIIK-II 60mm	294	11.9	1.0E+02	1.1E+01	>100%
MOSAIIK-II 65mm	281	12.5	9.6E+01	1.5E+01	>100%
MOSAIIK-II 70mm	269	13.1	9.2E+01	2.0E+01	>100%
MOSAIIK-II 75mm	258	13.6	8.9E+01	2.6E+01	>100%
MOSAIIK-II 80mm	246	14.3	8.4E+01	3.3E+01	>100%
MOSAIIK-II 85mm	235	14.9	8.1E+01	4.4E+01	>100%
MOSAIIK-II 90mm	225	15.6	7.7E+01	5.7E+01	>100%
MOSAIIK-II 95mm	213	16.5	7.3E+01	7.4E+01	98.4%
MOSAIIK-II 100mm	203	17.3	7.0E+01	9.8E+01	71.3%
MOSAIIK-II 105mm	193	18.2	6.6E+01	1.3E+02	52.2%
MOSAIIK-II 110mm	184	19.1	6.3E+01	1.7E+02	38.0%
MOSAIIK-II 115mm	175	20.1	6.0E+01	2.2E+02	27.9%
MOSAIIK-II 120mm	166	21.2	5.7E+01	2.8E+02	20.3%

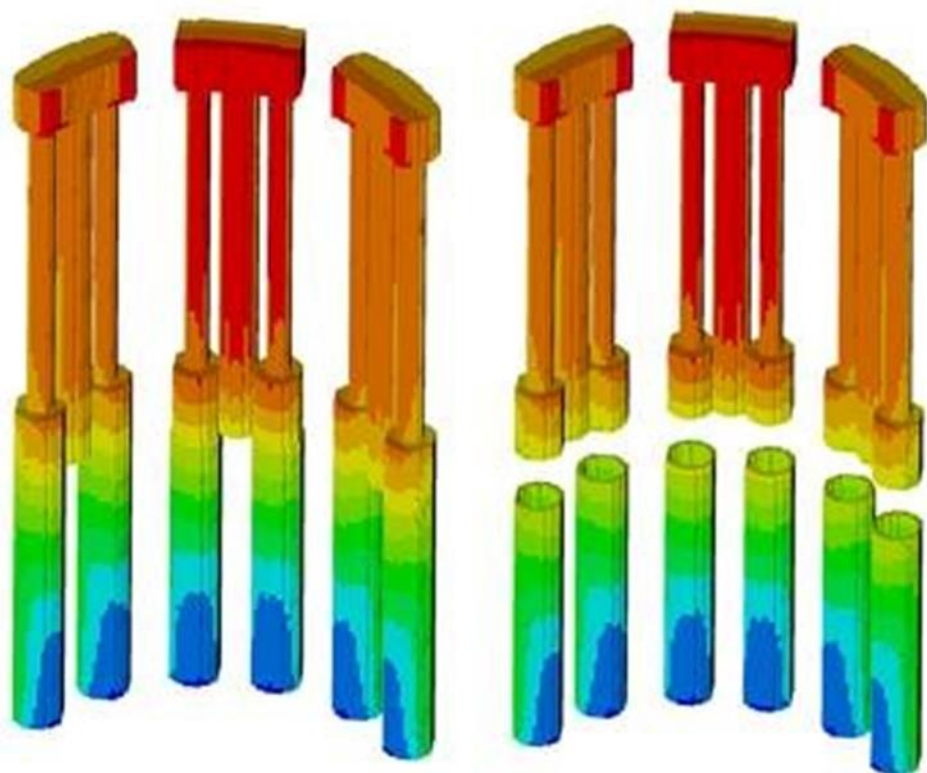
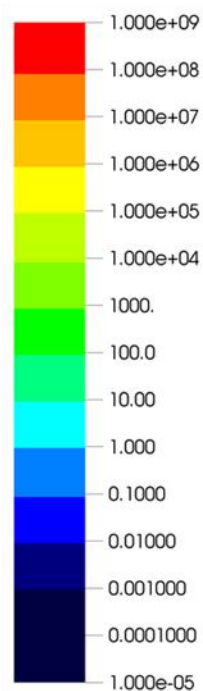


# Radiological characterization to lay the foundation of ALARA

## Characterization – Planning packaging

Jet pumps

Co<sup>60</sup> [Bq/g]



### Scenario 1

No cutting - whole jet pumps

63 MOSAIK-II 45mm

### Scenario 2

Top and bottom pumps separated

Top parts:

44 MOSAIK-II 50mm

Bottom parts:

3 LC-84

### Scenario 2

Scenario 2, but top parts separated into:  
close-to-core pumps and disagonal pumps

Top parts (close):

16 MOSAIK-II 60mm

Top parts (diagonal):

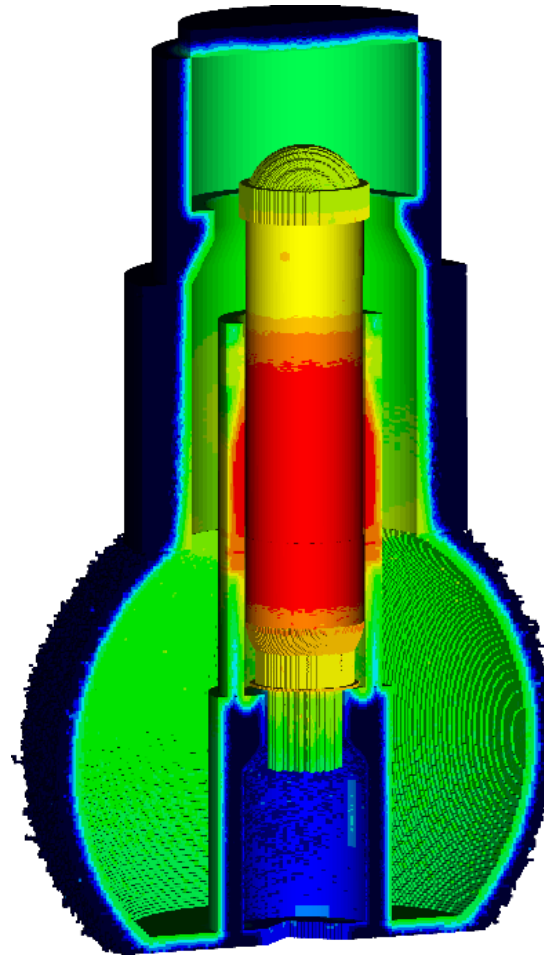
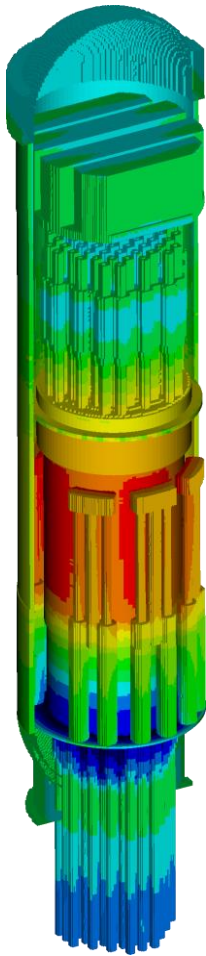
27 MOSAIK-II 40mm

Bottom parts:

3 LC-84

# Radiological characterization to lay the foundation of ALARA

Characterization – Defining clearance lines for dismantling



Radiological characterization to lay the foundation of ALARA



Thank you for your attention!